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**Title:** Modeling and optimizing XeF<sub>2</sub>-enhanced FIB milling of silicon.

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**Description:** p.255-61

**Abstract:** Wide variations in the dose enhancement factor observed when milling silicon using focused ion beam (FIB) XeF<sub>2</sub> gas assisted etching (GAE) prompted the development of a simple model of the GAE process. The model accounts for three material removal mechanisms: regular sputtering; gas-assisted sputtering; and spontaneous chemical reactions. An expression linking the dose enhancement factor,  $\epsilon_d$ , to the gas and milling parameters has been derived. Experiments show that  $\epsilon_d$  behaves as predicted; good quantitative agreement is achieved over wide ranges of milling parameters for  $\epsilon_d$  values between 20\* and 2500\*. Conditions required to minimize variations in  $\epsilon_d$  and maximize material removal rates,  $M$ , are derived. It is shown that if the dose per unit area per raster is below a threshold value, then  $\epsilon_d$  and  $M$  depend only on the average current density  $J$  (the area of the box divided by the beam current). A consideration of the  $J$  regimes used for front-side and back-side FIB work shows why changes in  $\epsilon_d$  have not previously been a problem but are inevitable when milling the large trenches characteristic of flip chip circuit modification work. While  $\epsilon_d$  changes dramatically, there is a region of  $J$  values for which  $M$  is approximately constant. (11 refs.)

**Subject:** Current density; Elemental semiconductors; Flip chip devices; Focused ion beam technology; Integrated circuit packaging; Machining; Optimisation; Semiconductor process modelling; Silicon; Sputter etching; Surface chemistry; Xenon compounds; XeF<sub>2</sub> enhanced FIB milling; Silicon; Modeling; Optimization; Dose enhancement factor; Milling; Focused ion beam XeF<sub>2</sub> gas assisted etching; FIB XeF<sub>2</sub> GAE; Material removal mechanisms; Sputtering; Gas assisted sputtering; Spontaneous chemical reactions; Milling parameters; Gas parameters; Material removal rate; Dose per unit area per raster; Average current density; Beam current; Back side FIB; Front side FIB; Trench milling; Flip chip circuit modification; Si

**Chemical:** XeF<sub>2</sub>; XeF<sub>2</sub>; F<sub>2</sub>; F<sub>2</sub>; Xe; F; Si

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